



AMSAT-NA Engineering Progress Report

JERRY BUXTON, NØJY
VICE PRESIDENT OF ENGINEERING



Fox-1 Program



Fox-1 Series Status

Fox-1 bus

- Standard systems
 - U/v FM repeater (A-D) or 30 kHz V/u linear transponder
 - STM32L151 IHU
 - MPPT or "LDO" (AO85) power supply
 - Six (3S2P) 1400 mAH NiCd A cells
- Hosted educational payloads
 - Penn State Erie MEMS gyro spin calculation experiment
 - Vanderbilt University Low Energy Proton experiments
 - Virginia Tech 640x480 jpeg camera experiments
 - University of Iowa "HERCI" experiment

Fox-1A Timeline

- 2009 – Program introduction
- 2012 – Fox-1A CSLI selection
- Completion timeline originally tied to UltraSat mission
 - 2H 2014 - NASA successfully fought for delivery in line with GRACE mission
 - VT camera delay used for leverage
- March 25, 2015 – Fox-1A delivered and integrated into P-POD at Cal Poly
- October 8, 2015 – Fox-1A launched from Vandenberg AFB
 - NRO GRACE Mission
 - Atlas V launch vehicle



Fox-1 Series Status

AO-85 (Fox-1A)

Two years on orbit!

- Nominal operation (given known quirks)
 - Battery 
 - Radios 
 - Telemetry 
 - Experiments 
- Excellent telemetry recovery
 - Thanks to Chris Thompson and FoxTelem!
 - 2,848,049 frames captured as of October 17, 2017
 - "Central Scrutinizer" tweaked and running well
- Excellent science data
 - VU ISDE has published several IEEE papers
 - Took our Fox-1 life-size model to Geneva for display
- AMSAT volunteers studying satellite parameters
 - Temperature, spin, battery, etc.



Fox-1 Series Status

AO-85 (Fox-1A)

Two years on orbit!

- 714 IHU/Bus Resets – GOOD
 - GOOD because it proves the design concept of IHU simple recovery
 - Many times users don't even know it
 - COR kicks in and QSOs continue without IHU
 - Yes, there is about a 20 second dropout during IHU reboot
 - Large percentage occur in SAA, smaller number in auroral zones, a few random ones
 - Possible temperature correlation, more often when satellite temperature is higher
 - AMSAT volunteers researching causes
- Several hundred resets early on, possible software issue in reboot sequence (elusive as always) addressed (hopefully) on RadFxSat-2
 - Not a requirement for RadFxSat-2 to work, same philosophy as the others

Fox-1 Series Status

AO-85 (Fox-1A)

Two years on orbit!

- Not without problems*
 - Antenna falling off
 - Led to new antenna fastening design by Lou
 - “-Z Protrusion exceeds envelope” (from MRR)
 - “~1 mm outside -Z envelope –result of vibration testing, knot tying lesson learned for future Fox-1 satellites”
 - Keeping current
 - Document updates not always known/shared
 - Resulted in red/green LED locations reversed, no threat to mission
 - Vanderbilt experiment locked up in flight model
 - Limited time to correct
 - Caused IHU to repeatedly reboot
 - Experiment software change; runs in raw telemetry mode only
 - In actual use VU is quite happy, software used on 1B as well
 - Some of the planned telemetry not available

* Common general theme found in all Fox-1 satellites

RadFxSat/Fox-1B Timeline

- 2013 – RadFxSat CSLI selection
- ELaNa XIV Mission Kickoff in August 2015
- December 2016 – Completed, ready for delivery
- August 16, 2017 – RadFxSat delivered and integrated into P-POD at Cal Poly
- November 10, 2017 – RadFxSat launch from Vandenberg AFB
 - JPSS-1 Mission
 - Delta II launch vehicle

Fox-1 Series Status

RadFxSat (Fox-1B)

- Not without problems
 - Initial attempt at DITL test revealed a short in one of the antenna burn resistor circuits
 - That fried the IHU deploy switch transistor due to high current
 - Replaced IHU with flight spare
 - That revealed an internal open in the RX antenna deploy circuit!
 - Determined to be on MPPT board
 - Replaced MPPT with flight spare



Fox-1 Series Status

RadFxSat (Fox- 1B)

- Not without problems – cont.
 - Testing of the IHU/MPPT rework revealed a birdie that kept the TX COR activated
 - Not related to the (above) short
 - Determined to be in RX, component with a bad solder joint
 - Disassembled, repaired, tested, reassembled



Fox-1 Series Status

RadFxSat (Fox-1B)

And - Some of the planned telemetry not available

- Not without problems – cont.
 - Post (official) DITL it was discovered that the transmit power was low
 - Investigation revealed that the antenna cable had come unseated from the connector during the previously mentioned rework.
 - +Z solar panel was removed, and the antenna cable was re-seated and secured.
 - Discussion of the process with Tyvak resolved that the DITL test was not invalidated by the process and would not need to be redone. (Email chain “RadFxSat Update” August 31, 2016)
 - Testing after the cable correction verified that the transmitter and the rest of the system are working as intended.

Fox-1Cliff Timeline

- 2014 – Fox-1Cliff Spaceflight commercial launch contract
 - Spaceflight SHERPA on Formosat-5 Mission
- March 2016 – Completed, ready for delivery
- Repeated launch delays (primary)
- 2017 – Alternate launch opportunities offered by Spaceflight
 - Chance to split up Fox-1Cliff and Fox-1D for some risk reduction
 - Now set for Spaceflight SSO-A Mission
- Launch sometime in 2018 (NDA stuff)



Fox-1 Series Status

Fox-1Cliff

- Not without problems
 - Flight model found to have short in bus lines
 - A real fun one to troubleshoot!
 - MPPT stopped working when IHU booted
 - That killed all of the solar power
 - Determined cause to be short between MPPT “solar safe” and IHU warning LED control lines
 - Cause was determined while at the hotel in Orlando, for Cliff/D environmental testing event!
 - We were at the end of the timeline, facing delivery, at that time
 - Fox-1D underwent shake and spin while we worked on 1Cliff

Fox-1D Timeline

- 2015 - Fox-1D Spaceflight commercial launch contract
 - Spaceflight SHERPA on Formosat-5 Mission
- March 2016 – Completed, ready for delivery
- Repeated launch delays
- 2017 – Alternate launch opportunities offered by Spaceflight
 - Chance to split up Fox-1Cliff and Fox-1D for some risk reduction
 - Now set for SSO PSLV launch from India
- Launch by the end of 2017 (NDA stuff)

Fox-1 Series Status

Fox-1D

And - Some of the planned
telemetry not available

- Not without problems
 - Further environmental testing required for PSLV launch qualification
 - +Z solar panel intermittent in post-environmental functional tests
 - Cause not fully understood, white wired Z panel connector for redundancy through unused pins
 - Receive not working in post-environmental functional tests
 - Determined to be in RX, component with a bad solder joint
 - Disassembled, repaired, tested, reassembled
 - Acceptance level environmental testing performed after reassembly

RadFxSat-2/Fox-1E Timeline

- 2016 – RadFxSat-2 CSLI selection
- ELaNa XX Mission Kickoff in July 2016
- December 2017 – Estimated completion
- January 2018 –MRR
- February 2018 – Delivery/integration
- Launch – End of 1Q 2018

Fox-1 Series Status

RadFxSat-2 (Fox-1E)

- Not without challenges
 - Power consumption of new experiments and ICR
 - Problems with conformal coating
 - Not curing
 - Wicking into connector pins
 - New IHU software
 - Undesired watchdog resets for “unknown” reasons
 - Not expected due to similarities to previous Fox-1 series

Fox-1 Series RadFxSat-2 (Fox-1E)

Linear Transponder prototype





ASCENT

ADVANCED SATELLITE COMMUNICATIONS AND EXPLORATION OF NEW
TECHNOLOGY
"THE SKUNK WORKS"



Summary: Great idea by Tom Clark, great decision by AMSAT Board of Directors to authorize and fund ASCENT!

GREAT NAME TOO, BUT THAT MAY BE A BIASED OPINION



What's next

A B C D E F...



(Gimmick, not actual logo)

GOLF

Greater Orbit,
Larger Footprint

Amateur Radio LEO Satellite Altitudes

- **AO-7** ≈ 1400 km.
- FO-29 ≈ 1200 km.
- SO-50 ≈ 650 km.
- AO-73 ≈ 650 km.
- AO-85 ≈ 650 km.
- **XW-2F** ≈ 520 km.
- ISS ≈ 400 km.



Higher is Better

- Larger footprint
 - More DX
 - More good passes per day (mid-latitude station)
- Orbit lifetime is longer
 - SSO typically 6 to 8 years
 - AO-7 - a lifetime
- Slower motion across sky
 - Longer passes
 - Less tracking movements

Higher is Harder

- More lift from launch vehicle = more \$
- Less launch opportunities (presently)
- NASA cap on CSLI subsidy
- Propulsion = \$\$\$\$
- Design
 - Thermal (colder)
 - More power required (batteries and solar panels)
 - Antennas (gain needed for link, CubeSats are small)
 - Radiation (Van Allen, SAA)
 - Orbital Debris (25 year rule)



What is GOLF? Basic idea: Progression of CubeSats – “Fox-2”

- Continued growth of CubeSat abilities
 - SDR
 - Deployable solar panels
 - Progression of our engineering team/capabilities
- Continuation of CSLI educational launch opportunities and partnerships

What is GOLF?

New challenges

- Platform for developing, testing, learning, and gaining proficiency New Technology
 - ADAC, propulsion, collision avoidance
- Any higher orbit whether LEO, MEO, HEO, GEO (not including rideshare) must meet orbital debris requirements
 - Develop and learn de-orbit capability (passive or active) for all future missions
- Following Fox-1, continues to regularly populate amateur radio satellites providing coverage for years to come
- Hands on knowledge and experience builds team capability for HEO

What are the Opportunities?

- 3U CubeSat development provides versatility
 - Mission specific radios, power, experiments
 - HEO spaceframe development
- Series of birds provides better coverage
 - Greater Footprint allows more coverage by less satellites
- Establishing track record for long missions, orbits > 25 years
- Continued/expanded partnerships with Universities, NASA, others
- Exploration and development
 - GPS, linked comms, etc.

What are the Opportunities?

- Variety of bands/modes provides more options and interests to our customer
 - e.g. combinations of 15m, 10m, 2m, 70cm
- Five and Dime
- Fun for Engineering Teams (this is a hobby)
- Increased membership, interest, donations



Where do you start GOLF?



GOLF-T!

(AS IN GOLF TEE)

GOLF-Trial opportunity

- Came about as a result of our partnership with Ragnarok Industries on CQC
- Uses ADAC and power systems developed for Heimdallr (CQC)
- SSO launch (or better if possible) as early as 2H 2019

Benefits

- Knowledge gained, not just hardware and a manual
- Ability to acquire same hardware for other GOLF missions
- Opportunity to fly ASCENT projects that have been in development
 - Realizes the purpose of ASCENT
 - Real on orbit operation, evaluation, experience - ongoing development
- Opportunity to develop/test flexible 3U spaceframe (ongoing)
- Opportunity to develop/test a variety of deployable solar panels (ongoing)

Hardware Overview

AMSAT PROVIDES

- 3U spaceframe
- Solar panels
- Five and Dime SDR
- U/v SDR
- U/v Programmable digital command transceiver "Radiation tolerant IHU using the TMS570"

AMSAT PROVIDES

- "Radiation tolerant U/v Linear Transponder"
- Antennas
- University experiment (VU)
- Five and Dime station support
- Ground command and control

Hardware Overview

RAGNAROK PROVIDES

- Star trackers*
- IMU
- GPS receiver
- Flywheels*
- Magnetic torque rods
- Flight computer*

RAGNAROK PROVIDES

- EPS Battery management*
- EPS Power distribution*
- Panasonic 18650B battery cells
- Interface, wiring, enclosure

* Ragnarok design/build



QUESTION AND ANSWER SESSION

AMSAT ENGINEERING TEAMS